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Influence of Specific Features of Twin Arc Welding on Properties of Weld Joints

M A Sholokhov[1], A U Melnikov[2] and A M Fiveyskiy[2]

[1] Ltd SHTORM, Yekaterinburg, Russia
[2] Ural Federal University named after the first President of Russia B N Yeltsin, Yekaterinburg, Russia

e-mail: au_melnikov@mail.ru

Abstract. The present article covers the influence of standard and narrow gap twin arc welding on properties of weld joints from high-strength steels. While analyzing microsections we established that distribution of microstructure and phase terms, as well the distribution of micro-hardness, were more homogeneous under narrow gap twin arc welding.

1. Introduction

Regarding the manufacturing process of special-purpose machinery the most expensive and time-consuming things to produce are thick-walled housings where welding takes over 50% of the total amount of work [1-2]. Why this process is so time-consuming might be explained by thickness of weld materials and the usage of joints with bevel preparation. Use of high tensile medium alloy steels with derated weldability for manufacturing of housings of special-purpose machinery requires the development of special welding technique that will allow us to get solid weld seams. It is important to note, that the straight welds and fillet or I-shaped welds are pretty extended [3]. All that predetermines worthwhileness of usage of automatic welding. Increase of productivity and decrease of defect formation, improvement of welding process might be achieved by gas-shielded multi arc welding [4-8].

Mechanical, physical-chemical and performance characteristics of weld seam metal and heat-affected zone (HAZ) are determined by whole range of factors, such as structural phase composition of all layers of weld seam because of that a comprehensive research of their formation under different welding techniques appears to be a relevant applied research task.

2. Experimental method

To determine special aspects of the influence of multi arc welding on characteristics of weld joints we carried out a series of experiments. The welding was done as gas-shielded single / multi arc welding (Ar+CO2) with welding wire such as: OK 12.51 - for the first arc, ER307Ti for the second arc. An angle of V-shaped preparation (groove angle) of welded sheets with thickness 20 mm was 60° (area of preparation 231 mm^2) or 12° (area of preparation 122 mm^2). As the material for samples we used high-tensile-strength steel 30CrMnSiN, which is commonly used for manufacture of housings for special-purpose machinery.

After welding of samples, the templates were cut out for micro structural analysis (Figure 1). The analysis was carried out using raster electron microscopy of high resolution Quanta-200 (produced by

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FEI Company, Holland, USA) and additionally equipped with Pegasus system, which included a tool for structural and grain flow analyses by Electron Backscatter Diffraction (EBSD) and Energy Dispersive Spectroscopy (EDS).

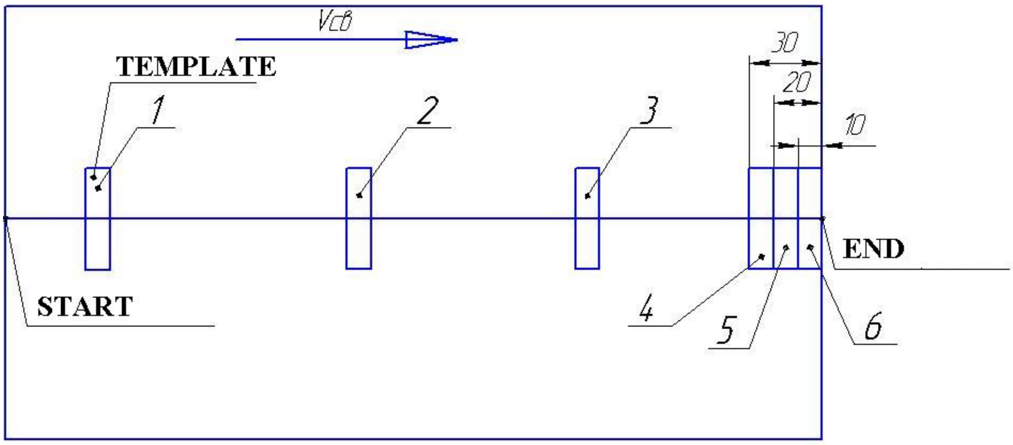


Figure 1. Scheme of templates cutting out from the sample weld seam

By spectrometer, produced by "EDAX", recorded characteristic X-ray excited chemical elements and measurement of their weight (and atomic) ratio in the test material, the elements are detected in a range from Borium to Uranium; energy resolution on line KαMn not less than 160 electrone-volts.

The welding mode is given in Table 1. Regulation of thermocycle under twin arc welding was carried out automatically due to variations of the distance between arcs from 50 to 200 mm. During welding the heating temperature of samples was recorded with 6 thermocouple-sensing elements, 3 of them were set in the middle of the sample in heat-affected zone (HAZ) within different distances from weld seam axis (4, 6, 8 mm) and at the end of the seam within equal distances from weld seam axis, the same as in point 1 (4 mm) in template positions 4, 5, 6. Example of thermal cycles of heat supply and cooling after the second pass in analyzing points, the allocation of thermocouple-sensing elements under twin welding of sample 07 (distance from 100 mm within arcs) are given on Figure 2. Indicative macrosections of weld seams are presented on Figure 3.

Table 1 – Welding mode parameters for samples

Parameter	Single arc welding	Twin arc welding
Current at the first/second arc, A	300	300/300
Voltage at the first/second arc, B	33	31/33
Welding speed, m/h	20	40
Wire feeding speed at the first/second arc, mm	11.0	10,4/11,0
Diameter of welding wire at the first/second arc, mm	1.2	1.2/1.2
Electrode stick-out at the first/second arc, mm	20	20/20

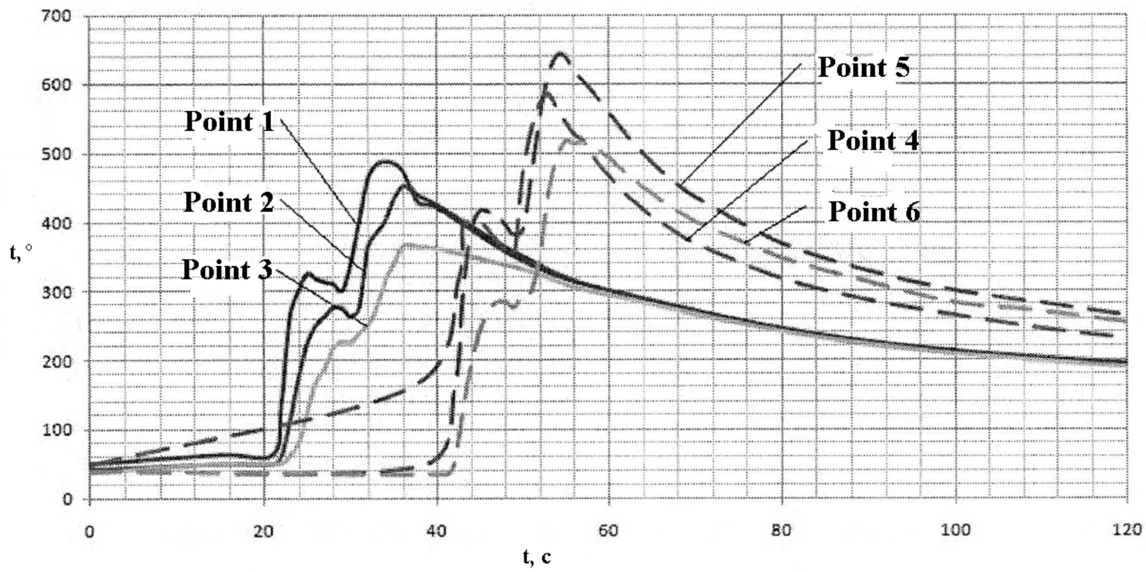


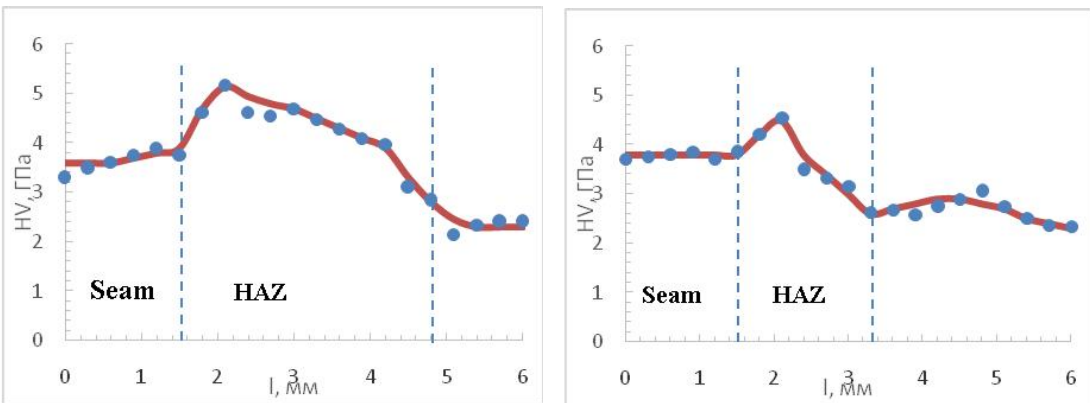
Figure 2. Indicative thermal cycles in analyzing points under twin arc welding (distance between arcs 100 mm), the second pass

a) b)

Figure 3. Macrosections of weld seams under twin arc welding with the distance between arcs 100 mm: a) bevel angle is 30°; b) bevel angle is 6°

3. Results and Discussion

To analyze the influence of twin arc welding on the properties of weld seams we measured micro-hardness at the cross-section. Indicative allocation of micro-hardness is presented on Figure 4.



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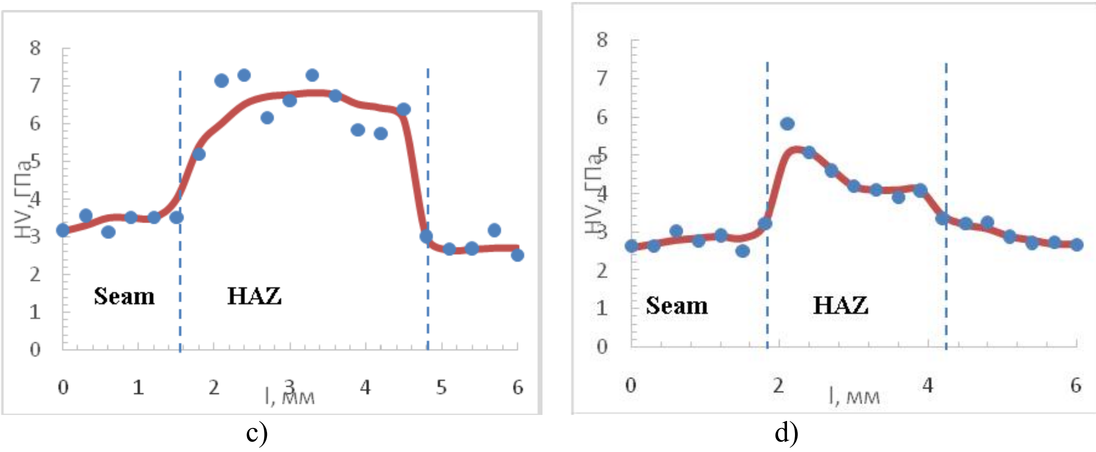

Figure 4. Allocation of micro-hardness at the cross-section under twin arc welding: a) bevel angle 6°, to the surface of a seam; b) bevel angle 6°, to the bottom of a seam; c) bevel angle 30°, to the surface of a seam; d) bevel angle 30°, to the bottom of a seam.

To sum up the obtained results of micro-hardness measurement, we need to indicate the following:

HAZ has greater micro-hardness in comparison to the hardness of weld seam metal, as well as matrix steel plate out of HAZ.

HAZ in all examined cases is more distinctive within the width (reaching approx. 3 mm) to the surface of a seam in comparison with HAZ, that is spread at a seam room, that 1.2 – 1.5 times narrower.

A higher value has micro-hardness of the upper part of HAZ than of the lower part of HAZ that joins the root of a weld seam.

In a way micro-hardness scans are similar under single and twin arc welding.

Less shown as for micro-hardness values near-weld area HAZ of narrow grooves with bevel angle 12°.

Besides measurement of micro-hardness at the cross-sections we carried the analysis of microstructure of seams, heat affected zones and main metal. Indicative microstructure of different parts of cross sections is presented on Figure 5 and Figure 6.

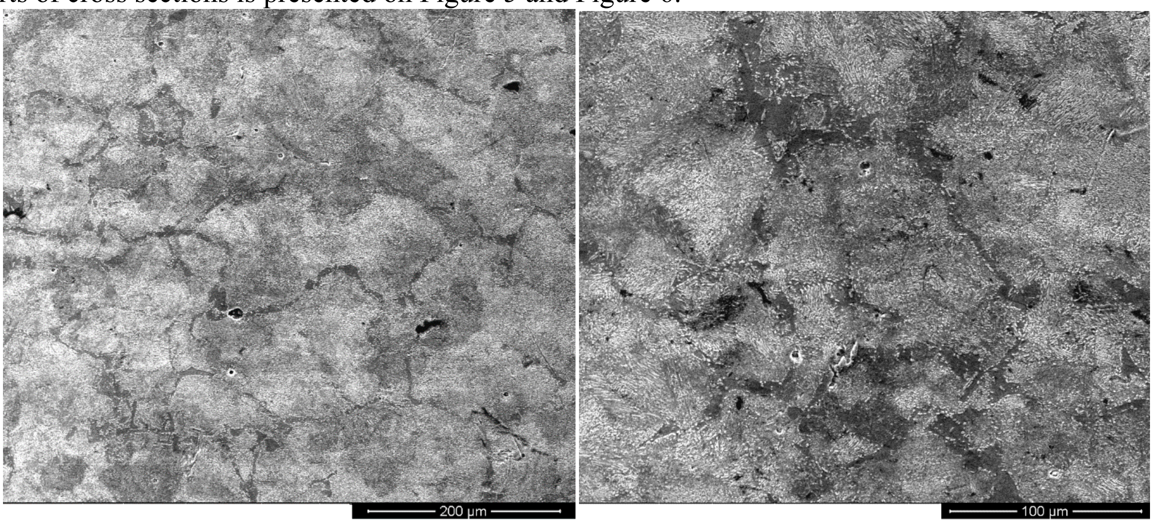

Figure 5. Typical microstructure of main metal of samples within 5 mm from a seam

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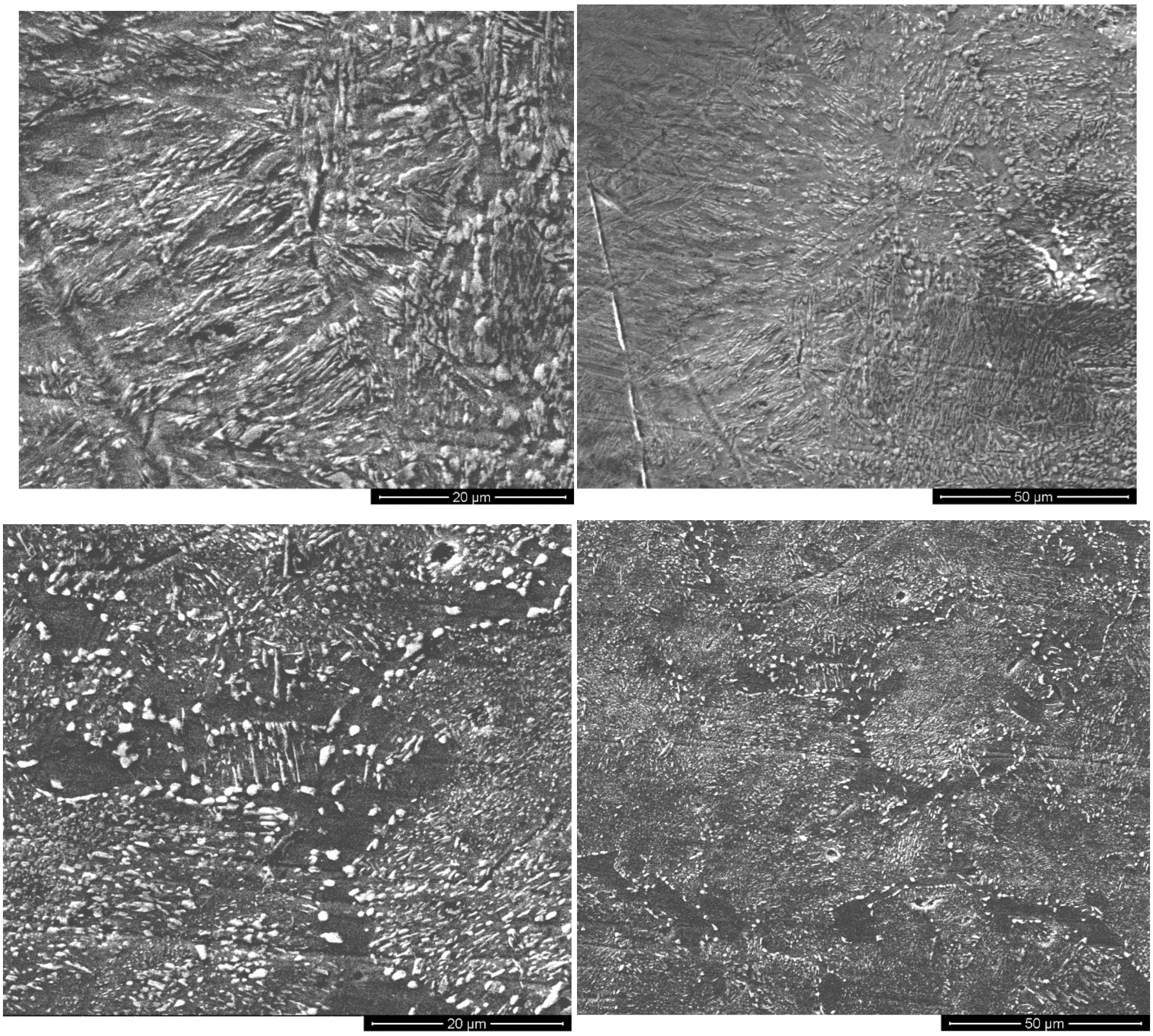

Figure 6. Typical microstructure of a sample in HAZ under twin arc welding (distance between arcs 100 mm)

Based on the analysis of microstructure we can come to the following conclusions:

1) In close to the weld seams areas, HAZ in all cases in prior austenite grain we observed colonies of laminar morphology, but within borders there were no globular crystalline α-phase particles, typical for initial steel structure of a plate. Such structure might be assigned to bainitic phase and determined by intense overheating of steel in a close distance to the weld seam, that assured a reverse change of perlite to austenite and its bainitic hardening.

2) In microstructure of HAZ located between bainitic and main globular perlitic (matrix) that is far from the weld seam we can see domination of thin plate perlite with a certain amount of perlitic areas with globalized finely dispersed cementite. This microstructure set alongside with bainite occurred as a result of dissolution of the initial under heating process and then under cooling in the decay to thin plate perlite.

3) As for the depth of HAZ (from the surface of a cross-section – the first line to the bottom where the root weld is located– the third line) thin structure of bainite and neighboring intermediate perlite changes: the thickness of bainetic paltes increases as well as the thickness of plates and equiaxed particles of cementite in perlite colonies. On the borders of grains we can see areas of α-феррита (on photos wide black layers). In total such morphology is typical more for main fundamental state of steel perlite.

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4) Under twin arc welding with bevel angle of 60°, microstructure of bainite and intermediate perlite in HAZ is more organized.
5) In case of single / twin arc welding with bevel angle of 12° in HAZ we can also see beinite layer and only then finely dispersed perlite. With that a perlite area hardly differs from neighboring matrix of steel out of HAZ, but bainite morphology in forms of packs was more structured and contained particles of finely dispersed cementite, in general it represents less distortion and lower initial stresses of microstructure. This correlates with data obtained from measurements of micro-hardness.
6) In general HAZ with narrow gap stood out by larger microstructure and phase homogeneity, that makes her closer to a main metal of steel plate. This results from the measurements of micro-hardness.

4. Conclusion
As can be seen from the above, according to the results of carried examinations we can come to a conclusion that usage of narrow gaps and twin arc welding influence in a positive way microstructure and characteristics of weld seams of high-tensile-strength steel.

References
[1] Rakhmatullin T A: Проблемы внедрения зауженных разделок при сварке корпусных конструкций специальной техники [Problems of implementation of narrow gaps under welding of housing for special-purpose machinery]. Rakhmatullin T.A., Sholokhov M.A., Buzorina D.S. News of Higher Educational Institutions. Mashinostroyeniye, 2012 (4) 64-66.
[2] Sholohov M A Перспективные технологии и оборудование для сварки по узкому зазору корпусных конструкций специальной техники [Advanced technologies and equipment for the narrow gap welding of hull structures of special equipment] Weldihg and Diagnostics 2015 (5) 46-51.
[3] Sterjovski Z Weld-end solidification cracking in pulsed-tandem gas metal arc welding of naval steels / Sterjovski Z., Bayley C., Donato J., Lane N., Lang D. // Welding Journal 2014 (93) 145-152
[4] UEYAMA T Higi-speed welding of steel sheets by the tandem pulsed gas metal arc welding system / Ueyama T., Ohnawa T., Yamazaki K., Tanaka M., Ushio M., Nakata K. // Transactions of JWRI 2005 (34) 11-18
[5] ISO 13847,2000. Petroleum and natural gas industries -- Pipeline transportation systems -- Welding of pipelines.
[6] Industry standard of Gazprom 2.2.3-137-2007. Инструкция по технологиям сварки при строительстве и ремонте промысловых и магистральных газопроводов. Часть II. [Instruction on welding technologies under building and repair of trade and main pipelines]
[7] DDD 153-006-02. Инструкция по технологии сварки при строительстве и капитальном ремонте магистральных нефтепроводов [Instruction on welding technologies under building and repair of main pipelines].
[8] Efimenko L A: Формирование структуры сварных соединений высокопрочных сталей при автоматической сварке в защитных газах [Structure formation of weld joints of high-tensile-strength steel under automatic shielding gas welding]. Efimenko L.A., Kapustin O.E., Kapustin A.A., Shkapenko M.V., Karasev D.N. Rabotinskii D.N. Pipeline transport. Theory and Practice, 2012 (4) 34-42.